INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 17, No. 1, p. 48-57, 2020
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Environmental conditions and zooplankton community structure in five ponds in Bertoua City, Cameroon (Central Africa)

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Article published on July 24, 2020

Key words: Ponds, Physical-chemical variables, Zooplankton, Cameroon

Abstract

The degradation of surface water quality in Cameroon is linked to the absence of a functional waste management strategy. For such a strategy to be efficient, a general understanding of aquatic ecosystems will be of importance, these management strategies are particularly lacking in the eastern part of the country. To better understand and appreciate the ecosystems in the town of Bertoua, five ponds where chosen for the physicochemical and zooplankton communities analysis. Sampling on these ponds was conducted from March 2016 to April 2017 on a monthly basis. Samples for physicochemical analysis were collected at 20cm below water surface at the middle of each pond and measured were done following the recommendations of Rodier and Alpha. Biological samples were collected by filtering 50 liters of water through a 64µm mesh opening sieve. Identification was done using standard methods and identification keys. One-way ANOVA analysis was conducted to assess the potential differences between the different ponds base monthly observations. Although they are all hypereutrophic, with regard to the values of the physicochemical parameters, the five ponds showed no significant difference between them but, the structure of the zooplankton community remains very diverse. 118 zooplankton species have been identified in the five ponds. The distribution of zooplankton in these hydrosystems was mainly governed by the presence of organic matter. This study sheds light on the status and biological diversity of ponds in eastern Cameroon, data on which to rely to develop management strategies.

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Introduction

Like other aquatic environments, ponds are characterized by linked food chains that form food webs with interacting populations of fish, macroinvertebrates, zooplankton, phytoplankton and bacteria that also interact with their living environment (Dussart, 1980, Zébazé Togouet, 2000). Ponds also provide habitats for waterbirds and contribute to economic activity to the extent that they allow the development of fish farming. This harmony easily disturbed by anthropogenic activities. Despite being sites of high biodiversity, pond communities are not generally considered in conservation programs, various human activities such as urbanization, farming etc, contribute in deteriorating water quality and making them unsuitable for biodiversity maintenance. Today, ponds around the world are in crisis because of continues population growth and pressure from anthropogenic activities (Cairns, 2005). The case of East Cameroon is no exception. Indeed, with the uncontrolled settlement of populations in the watersheds and the development of industries, ponds are often used as receptacles for various domestic, agricultural and industrial effluents (Vikram Reddy, 2005), resulting in a degradation of water quality via accelerated eutrophication, especially in highly populated areas. However, since this part of Cameroon is rapidly developing, it is important to measure the impact of growing pollution on the water systems so as to establish a protection programs for the different water bodies that have not yet been affected by the pollution and a better restoration program for those sites that have been degraded. Very little hydrobiology work has been done so far in this forest area of the country which shows a humid tropical climate. Development in this area should be subject to systematic control to prevent environmental damage. Such conservation is of interest not only for the ecological restoration component, but also with respect to human health and ecosystem services.

Studies to determine the physicochemical and biological status of ponds in particularly understudied geographic regions are needed in order to assess their current states and to propose adequate measures of their management to local authorities. This current study focuses on urban ponds typical of the East region of Cameroon.

In other parts of the country ponds have been found to be in poor ecological states and we sought to determine whether ponds in East region of Cameroon are similarly degraded. The characterization of physicochemical and biological parameters of these hydrosystems was carried out to provide an initial assessment of ecological state that could be of use to managers in the region for the development of aquatic ecosystem conservation programs.

Materials and methods

Study site

The study focused on determining the ecological state of five ponds within the city of Bertoua, capital of the East region of Cameroon situated between altitude 400 and 900m as shown on Fig. 1 (Tsalefac *et al.*, 2003). The temperature is elevated throughout the year, attaining a maximum of 30°C, with an average between 23°C and 25°C. Precipitation in the region is relatively abundant (1500 to 2000mm of rainfall per year).

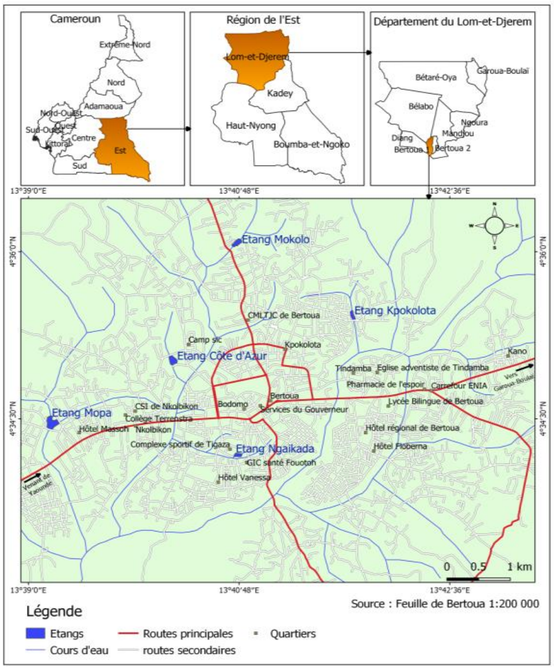

Fig. 1. Study area showing the location of the five Bertoua ponds (Mokolo, Kpokolota, Ngaikada, Côte d'azur and Mopa).

Sampling

Sampling was carried out from March 2016 to April 2017 in five ponds (Table 1). Mokolo pond (Fig. 2a) is surrounded by vegetation marked by the presence of macrophytes, some of which are floating and others emergent species growing at the banks.

The watershed contains some houses and food crops. The watershed of Kpokolota pond (Fig. 2b) is surrounded by several sources of water pollution from dwellers in the watershed, nearby garbage dumps, as well as, latrines built at the edge of the pond. Ngaikada pond (Fig. 2c) is covered with macrophytes that inhibit light penetration. Côte d'azur pond (Fig. 2d) is a large body of water bordered by herbs, trees and shrubs and with many floating-leaved macrophytes covering the surface of the water. Mopa pond (Fig. 2e) is characterized by a belt of vegetation located on the shore surrounding the pond, the presence shrubs that completely colonize the surface of the pond.

Table 1. Geographical coordinates of the five study ponds.

	Mokolo	Kpokolota	Ngaikada	Côte d'azur	Mopa
Latitude	04°36.065'N	04°35.432'N	04°34.175'N	04°34.992'N	04°03.408'N
Longitude	013°40.759'E	013°41.770'E	013°40.759'E	013°40.237'E	013°40.188'E
Altitude (m)	658	654	655	654	650

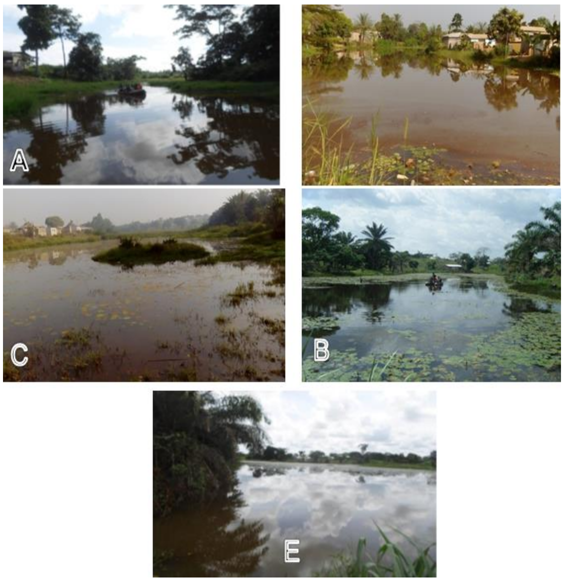

Fig. 2. Photos showing each of the five study ponds with (a) Mokolo pond, (b) Kpokolota Pond, (c) Ngaikada Pond, (d) Côte d 'azur Pond and (e) Mopa pond.

Sampling were carried monthly for a period of 14 months, thereby including the dry season and the rainy season. Water was sample from the surface down to the depth of 0.5 m, as it is normally done for shallow lakes (maximum depth <3 meters) (Zalewski *et al.*, 2004). Temperature (°C), pH, and electrical conductivity were measured *in situ* respectively by means of a mercury thermometer, a portable pH meter (SHOTT GERÄTE CG 812) and a HACH TDS/ portable conductivity meter. During the study period, sampling was regularly done from 9 to 12am.

Physicochemical parameters such as suspended solids, percentage of dissolved O_2, electrical conductivity, pH, temperature, orthophosphate, nitrite and ammonium were measured from water samples collected in 1000mL polyethylene bottles at the surface by directly filling, without bubbles. Water was also collected in the center of each pond with a 6L Van Dorn bottle. In the laboratory nitrogen and phosphorus variables were measured using a spectrophotometer (HACH DR/2000 spectrophotometer) according to standard techniques (APHA, 1985).

The chlorophyll "a" was measured by the spectrophotometric method. Zooplankton samples were from the surface to the depth of 0.5m and five samples of 10L of water each were then filtered through a 64 µm mesh opening sieve. A 100mL subsample of this total was fixed with 5% formalin and was used for identification and counting. For the determination of zooplankton species richness, a composite sample was obtained after mixing the subsamples from the five sampling points in each pond. Using the technique of (Legendre and Watt, 1972), we identified and counted rotifers, cladocerans and copepod taxa under a WILD M5 binocular microscope and an OLYMPUS CK2 UL WCD 0.30 microscope, using the taxonomic keys of (Koste and Shiel, 1991, Pourriot and Francez, 1986 and Shiel, 1995). Identification of rotifers was based on the shape of the chitinous shell or lorica, the number and arrangement of thorns while that of cladocerans and copepods was possible by observation, after dissection of individuals under an inverted microscope of mark Olympus CK2 ULWCD 0.30, focused on the cephalic region, the carapace and the post-abdomen. Counts were done on 10mL subsamples for each composite sample, through duplicate counting in 30mm diameter Petri dishes crisscrossed into small 3mm squares. At least 100 individuals were counted each time per sample, if this was not the case, counting continued until the sample is all used up. The density of the individuals in the sample was calculated using the following formula: D= $\frac{v}{v'.V} \times n$ (expressed in ind.L^{-1}, with: v = total volume of the subsample; v' = volume of the subsample fraction poured into the Petri dish for counting; V = volume of filtered water in the field; n = number of individuals contained in v'. The Shannon & Weaver index made it possible to quantify the heterogeneity of the biodiversity of the ponds by taking into account the number of species and the abundance within each of these species, while the Pielou index made it possible to measure the pattern of distribution of abundances between species.

Data analyses

All statistical analyses were carried out using R statistical environment (R Core Team 2017), the Fig.s being created using "ggplot2". One-way ANOVA was conducted to assess the potential differences and magnitude of change between the five ponds using the monthly observations as replicates. Post hoc Tukey tests were used to determine significant differences between the ponds under observation. Given that there will be generational turnover in the zooplankton and multiple turnover periods for the physicochemical variables across a monthly timescale; this use of different temporal observations as replicates is justified.

Results

Physicochemical characterization of the environments

All values of physicochemical parameters are listed in table 2. Averaged pond temperatures values are 26.3 ± 0.27°C in Kpokolota; 26.17 ± 0.37°C in Ngaikada, 27.59 ± 0.44°C in Côte d'azur, 28.57 ± 0.89°C in Mopa and 24.46 ± 0.29°C in Mokolo. In general, the average temperature of the water ranges between 2 and 3°C with an overall average of 26.62 ± 0.37°C. There were no significant differences between the ponds (p-value > 0.29).

Table 2. Geographical coordinates of the five study ponds (Legend: Min = minimum; Max = maximum; Ave = Average; Mo=Mokolo ; Kp=Kpokolota ; Ng= Ngaikada ; Ca= Côte d'azur ; Mp= Mopa).

Parameters		$Pond_{Mo}$	$Pond_{kp}$	$Pond_{Ng}$	$Pond_{ca}$	$Pond_{Mp}$
Temperature (°C)	Ave ± σ	24.46±0.29	26.3±0.27	26.17±0.37	27.59±0.44	28.57±0.89
	Min-Max	23-28	24-29	24-30	25-33	26-33
pH (UC)	Ave ± σ	6.53±0.20	6.39±0.17	6.34±0.19	6.24±0.18	6.35±0.19
	Min-Max	5.15-8.63	5.13-7.5	5.22-7.54	4.9-7.42	4.9-7.36
Dissolved Oxygen (%)	Ave ± σ	60.97±3.15	58.35±2.61	56.73±3.00	59.65±2.98	61.7±3.34
	Min-Max	31-88.6	35.3-84.7	33.9-83.9	36-83.9	27.8-87.8
Electrical Conductivity (µS/cm)	Ave48± σ	47.21±3.52	69.92±3.86	69.74±4.17	45.48±3.15	43.77±3.46
	Min-Max	31.7-81	53.6-103	48-104	31.7-87	29.9-88
Suspended solids (mg/L)	Ave ± σ	23.06±4.85	41.17±14.08	40.25±14.41	26.25±4.99	24.56±7.81
	Min-Max	1-75	4-230	1-235	0-92	0-138
Nitrates	Ave ± σ	1.57±0.44	0.72±0.12	1.80±0.36	1.86±0.50	1.05±0.31
(mg/L NO_3^-)	Min-Max	0-9	0-1.7	0-5.5	0-12.1	0-5.6
Nitrites	Ave ± σ	0.003±0.001	0.048±0.038	0.014±0.006	0.016±0.007	0.014±0.006
(mg/L NO_2^-)	Min-Max	0-0.017	0-0.1	0-0.1	0-0.17	0-0.1
Ammonium	Ave ± σ	0.87±0.16	1.00±0.17	1.16±0.21	1.15±0.22	1.20±0.30
(mg/L NH_4^+)	Min-Max	0.01-2.49	0.01-2.27	0.02-2.54	0-3.42	0.11-4.21
Phosphates	Ave ± σ	6.60±1.49	4.14±0.94	4.05±0.90	3.35±0.87	4.43±0.89
(mg/L PO_4^{3-})	Min-Max	0-24.2	0.1-13.6	2-16	0-12.5	0-10.7

The pH values remained close to neutral, although a few ponds were slightly acidic. No significant differences were found in the mean pH value between the different ponds, nor across the various months (p-value > 0.39). Annual mean pH values were 6.24 ± 0.18 in Côte d'azur, 6.39 ± 0.17 in Kpokolota, 6.53 ± 0.20 in Mokolo, 6.35 ± 0.19 in Mopa and 6.34 ± 0.19 in Ngaikada. Conductivity values were similar and significantly lower in Côte d'azur (annual mean of 45.48 ± 3.15 µS.cm^{-1}), Mokolo (47, 21 ± 3.52 µS.cm^{-1}), and Mopa (43.77 ± 3.46 µS.cm^{-1}), than those observed in Kpokolota (69.92 ± 3.86 µS.cm^{-1}) and Ngaikada (69.74 ± 4.17 µS.cm^{-1}) that were both similiarly higher (ANOVA, p-value<0.001). The overall mean value of conductivity across all ponds was 55.23 ± 3.63 µS.cm^{-1}.

Average dissolved oxygen levels across the 14 months was approximately 62% across all ponds. There were no significant differences in dissolved oxygen means between the ponds with annual averages of: 59.65 ± 2.98% in the Côte d'azur pond, 58.35 ± 2.61% in Kpokolota, 60.97 ± 3.15% in Mokolo Pond, 61.7 ± 3.34% in Mopa, and 56.73 ± 3.00% in Ngaikada.

Most of the suspended solids (SS) values observed across the 14-months and in all five ponds were between 12.5mg. L^{-1} and 48mg. L^{-1}. ANOVA, followed by a Tukey test, indicated significant differences between Kpokolota and Mopa (p-value = 0.034). This difference was likely due to a few very high values observed in Kpokolota and only lower values were seen in Mopa. Mean annual concentrations of S.S were 26.25 ± 4.99mg. L^{-1} in Côte d'azur pond, 41.17 ± 14.08mg. L^{-1} Kpokolota, 23.06 ± 4.85mg. L^{-1} in Mokolo, 24.56 ± 7.81mg.L^{-1} in Mopa and 40.25 ± 14.41mg.L^{-1} in Ngaikada.

Amongst the nitrogen forms assessed, NH^{4+} concentrations varied from 0 to 3mg. L^{-1} with an exception of a few typically higher values observed in Côte d'azur and Mopa. Mean values across the 14-months in the different ponds did not differ significantly (p-value = 0.19) and were: 1.15 ± 0.22mg. L^{-1} in Côte d'azur; 1.00 ± 0.17mg. L^{-1} in Kpokolota; 0.87 ± 0.16mg.L^{-1} in Mokolo; 1.20 ± 0.30mg. L^{-1} in Mopa and 1.16 ± 0.21mg. L^{-1} in Ngaikada.

Nitrite (NO_2^-) concentrations varied between 0 and 0.17mg. L^{-1} across all months and all ponds, with most values concentrated around 0.01mg. L^{-1}. The highest concentrations were recorded at Kpokolota. It was only between Ngaikada, and Côte d'azur ponds that significant differences in nitrite values were observed (p-value = 0.044). In order of decreasing concentration, the following values were found: 0.048 ± 0.038mg. L^{-1} in Kpokolota, 0.016 ± 0.007mg. L^{-1} in Côte d'azur, 0.014 ± 0.006mg. L^{-1} in Ngaikada and Mopa Ponds and 0.003 ± 0.001mg. L^{-1} in Mokolo. Nitrate (NO_3^-) concentrations varied between 0 and 12.1mg. L^{-1} across all months and all ponds.

The highest concentrations were recorded at Côte d'azur. There were no significant differences between phosphate ($PO^{-3}{}_4$) values (p-value = 0.78) with half of the values being < 6mg. L^{-1}. Mean values across months from greatest to least were: 6.60±1.49mg. L^{-1} in Mokolo, 4.43±0.89mg. L^{-1} in Mopa, 4.14±0.94mg. L^{-1} in Kpokolota, 4.05 ± 0.90mg. L^{-1} in Ngaikada, 3.35 ± 0.87mg. L^{-1}in Côte d'azur.

Biological variables

The distribution of Chlorophyll "a" in the different ponds (Fig. 3) is more oriented towards the highest values, varying from 0 to 150µg.L-1. The decreasing order of Chlorophyll "a" concentration in the different ponds is as follows: Kp, Mp, Ca, Ng and finally Mo. The boxplots (Fig. 3) show us outliers at the pond Kp, Mo and Ng.

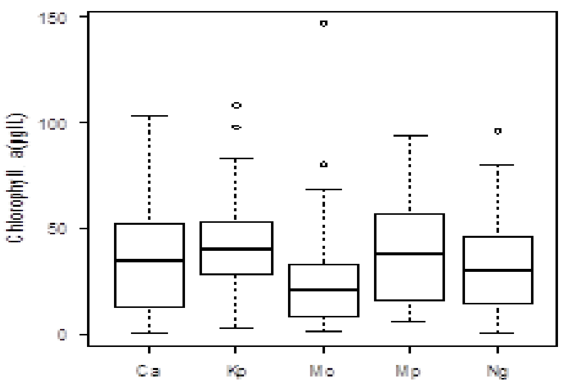

Fig. 3. Average chlorophyll "a" values over each month in ponds.

During the study period, a total of 118 (Table 3) taxa of zooplankton were identified across the five ponds. 82 organisms were identified up to the species level, 33 up to the genus level and 2 at the group or sub-group level to which they belong (Bdelloïds and Ostracods). This gave a total of 62 species and subspecies of rotifers, 9 species of copepods and 45 species and subspecies of cladocerans and of course 1 individual from the group of Ostracods. Irrespective of the pond considered, the richest and most abundant rotifer family was Lecanidae, followed by the Brachionidae. Species richness varied between 63 taxa in Mokolo and 75 taxa in Mopa (Fig. 4). Rotifers were the most abundant group of zooplankton in all five ponds (Fig. 5). This group represented 53.80% of zooplankton abundances in Mokolo, 54.25% in Kpokolota, 75.35% in Ngaikada, 60.52% in Côte d'azur and 65.22% in Mopa.

Table 3. List of taxa collected in the five study ponds.

Group	Species	Group	Species	Group	Species
	Ascomorphella sp		*Mytilina trigona*		*Diaphanosoma* sp1
	Asplanchna herricki		*Mytilina ventralis*		*Dunhevedia* sp
	Asplanchna priodonta		*Notommata grandis*		*Gurneyella* sp
	Bdelloïdes*		*Notommata pseudocerberus*		*Iliocryptus* sp
	Brachionus calyciflorus		*Notommata* sp		*Illiocryptus spinifer*
	Brachionus caudatus		*Notommata viridis*		*kurzia longirostris*
	Brachionus falcatus		*Philodinavus paradoxus*		*Kurzia* sp
	Brachionus leydigia		*Plationus patulus*		*Macrothrix goeldii*
	Brachionus quadridentatus		*Platyias quadridentatus*		*Macrothrix rosea*
	Cephalodella sp		*Polyarthra vulgaris*		*Macrothrix* sp
	Cephalodella ventripes	Rotifers	*Proales* sp	Cladocerans	*Macrothrix* sp1
	Collotheca sp		*Rotaria citrina*		*Moina micrura*
	Colurella obtusa		*Rotaria neptunia*		*Moina* sp
	Conochilus sp		*Rotaria rotatoria*		*Moina* sp1
	Dicranophorus grandis		*Scaridium longicaudum*		*Moinadaphnia macleayi*
	Dipleuchnis propatula		*Synchaeta* sp		*Oxyurella singalensis*
	Epiphanes macrourus		*Trichocerca bicristata*		*Oxyurella* sp
	Euchlanis callysta		*Trichocerca elongata*		*Pleuroxus chappuisi*
Rotifers	*Euchlanis dilatata*		*Trichocerca flagellata*		*Pleuroxus* sp
	Euchlanis meneta		*Trichotria curta*		*Pleuroxus trigonellus*
	Euchlanis proxima		*Trichotria tetractis*		*Pseudosida bidentata*
	Gastropus hyptopus		*Acroperus harpae*		*Pseudosida* sp
	Hexarthra fennica		*Alona monocantha*		*Scapholeberis kingi*
	Kellicottia longispina		*Alona pulchella*		*Simocephalus serrulatus*
	Keratella faculata		*Alona rectangula*		*Simocephalus expinosus*
	Lecane bulla		*Alona* sp		*Ectocyclops* sp
	Lecane candida		*Ceriodaphnia pulchella*		*Halicyclops* sp
	Lecane closterocerca		*Ceriodaphnia quadrangula*		*Harpaticoides*
	Lecane cornuta	Cladocerans	*Ceriodaphnia* sp	Copepods	*Mesocyclops* sp
	Lecane curvicornis		*Chydorus angustirostris*		*Microcyclops* sp
	Lecane leontina		*Chydorus barroisi*		*Microcyclops varicans*
	Lecane luna		*Chydorus eurynotus*		*Thermocyclops crassus*
	Lecane lunaris		*Chydorus globosus*		*Thermocyclops* sp
	Lecane nana		*Chydorus latus*		*Tropocyclops* sp
	Lecane papuana		*Chydorus* sp		Ostracodes*
	Lecane quadridentata		*Chydorus* sp1		
	Lecane stichaea		*Chydorus* sp2		
	Lecane ungulata		*Chydorus sphaericus*		
	Lepadella ovalis		*Diaphanosoma brachyurum*		
	Lepadella patella		*Diaphanosoma* sp		
	Mytilina bisulcata		*Diaphanosoma* sp2		

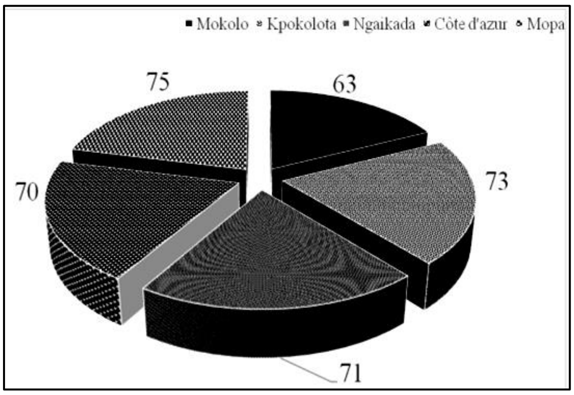

Fig. 4. Zooplankton taxa richness by pond.

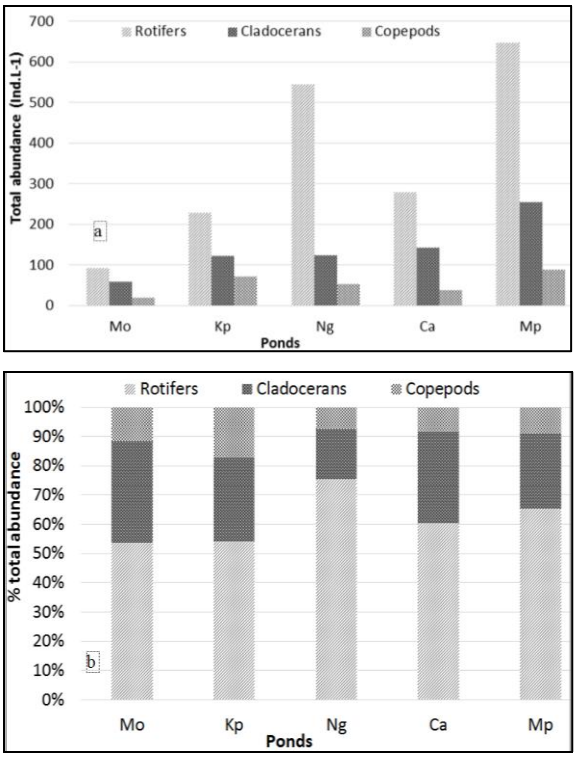

Fig. 5. Composition of the zooplankton groups in each study pond: a) Total abundance composition and b) Percent composition of the main groups.

Cladocerans represented 34.5%, 28.77%, 17.17%, 31.24%, and 25.81% of the zooplankton abundance in Mokolo, Kpokolota, Ngaikada, Côte d'azur, Mopa ponds respectively. Despite these low abundances, cladocerans were an important compartment of the planktonic communities (Fig. 5). Copepods contributed 11.7%, 16.98%, 7.48%, 8.24% and 8.97% zooplankton abundance in Mokolo, Kpokolota, Ngaikada, Côte d'azur, Mopa ponds respectively (Fig. 5). The Shannon and Weaver diversity index presented strong values, generally above 3.20, within and between ponds, and the Pielou index is almost higher than 0.70.

Discussion

The physico-chemical environment

Temperature was the environmental variable that varied the most. Despite this, the temperature range observed here remained within the bounds observed in other tropical lakes (Lewis, 1987, Nziéleu Tchapgnouo, 2016). The temperature directly attributed to the degree of vegetation cover found at the banks and the water surface of each pond, which affects the degree of illumination attaining the water column (Madomguia *et al.*, 2016). Furthermore, (Vannote *et al.*, 1980 and Qiu, 2013) found that in forest areas, temperatures vary less. This corresponds to the fact that water temperature was the lowest and varied the least in Mokolo pond (Tchegnebe, 2017); a pond which has a significant canopy presence that would reduce sunlight illumination of the pond.

A mean dissolved oxygen saturation (60%) across the different ponds indicates significant photosynthetic activity in these ecosystems during the day. This result conur with that of (Schlumberger and Bouretz, 2002) for fish ponds (50 to 62.5%). However, values in the lower range could be due respiratory activities at night in the plant and to the activity of aerobic bacteria present in the medium which consume oxygen in the water.

The waters of the ponds are slightly acidic which according to (Zébazé Togouet, 2000), is likely to result from the acidic nature of the region's soils. These values are similar to those observed in two other ponds in Yaoundé (6.83 and 6.82 CU), as well as in the Ossa lake complex (6.64) Mfou lake (6.95), and in Mvogo pond (6.95) (Mvogo, 2017, Nziéleu Tchapgnouo, 2006 and 2016, Kengne Tenkeu, 2014). It is important to note that the pH values observed close to the bottom end of the pond ranges around (6.5 - 9.0) which is recommended for the protection of aquatic life (MDDELCC, 2014). The average conductivity across the ponds is likely to be linked to a low concentration of nitrate (NO_3^-) in these ecosystems (Caplancq, 1982). The fairly large values of NH^{4+} denote significant mineralizing activity provided by bacteria.

Spatio -temporal distribution of zooplankton

From the 118 species of zooplankton identified during this study. An important presence of littoral and periphytic species was noted in all ponds and is attributable to the lateral exchange of material between pelagic and littoral zone common within shallow ponds. Furthermore, the shallow depth of the water column in the ponds suggests that, light reaches the bottom of ponds (Zébazé Togouet *et al.*, 2007), canceling out a possible stratification and creating essentially and entirely littoral habitats. Indeed, when ponds are "cleaned" by humans, macrophytes are often removed from the pelagic zone, thereby removing support and shelter for periphytic organisms, and this make the pond more accessible to pelagic organisms (Schlumberger and Bouretz, 2002). The taxa present must be tolerant enough to resist enrichment by the large amounts of organic matter. The predominance of rotifers over microcrustaceans (Cladocerans and Copepoda) in all the ponds is explained by the fact that rotifers are organisms that grow abundantly in waters rich in organic matter. Zooplankton communities dominated by rotifers are characteristic of advanced eutrophication (Angeli, 1980). Indeed, only taxa in this group are tolerant enough to strong enrichment of organic matter and depletion of dissolved oxygen which is a typical characteristic of eutrophication (Zébazé Togouet, 2008).

The predominance of rotifers could also be a result of negative growth conditions for crustacean zooplankton in these ponds. Cladoceran densities being the preferred prey for juvenile fish (Eawag News, 2012) could be limited by predation rather than by the quantity and quality of food available. While the copepods have a peculiar distribution, they highly variable conditions of the environment, and resist more rapid or less rapid fluctuations of the physicochemical or biological characteristics of the environment. The high values of the Shannon and Weaver index express an equal distribution of organisms in the environment. This is confirmed by the high Pielou index values; therefore, there is no characteristic dominance of one species over the others. However, considering that a ponds, by its diversity of habitats, the abundance of food resources and the stability of the environment, constitute an ideal living environment where a rich and varied fauna develops. This reaches a state of equilibrium in terms of its specific richness and the abundance of its zooplankton population before starting the downward phase of its evolution. By then, environmental conditions becoming difficult and only the specialized species are maintained and survive. If a pond is consider as an environment rich in nutrients, considering that the ponds studied have a great specific richness and thus evolve towards a state of equilibrium then, the progress towards their decline is inexorable.

Conclusions

The physicochemical and biological characterization of the studied ponds in the city of Bertoua-Cameroon revealed that the pond waters were polluted by anthropogenic activities. Biological analysis of the different organisms confirmed this hypereutrophic state since most of the species encountered are generally tolerant to significant enrichment of the environment.

Funding

The research was partly funded by "Agence Universitaire de la Francophonie" (AUF) – "Direction Régionale Afrique Centrale et des Grands Lacs" (DRACGL) grant number 6950/660/DRACGL 2018 AMBA/PFD.

Acknowledgments

The authors thank the Direction of Central Africa and Great Lakes Region (DCAGLR) of "Agence Universitaire de la Francophonie" (AUF) for the mobility grant from Cameroun to Canada and the Inter-University Research group in Limnology and Aquatic Environment (GRIL) of the University of Quebec in Montréal (Canada).

Conflicts of Interest "The authors declare no conflict of interest".

References

Angeli N. 1980. Interactions entre qualité des eaux et les éléments de son plancton. In : Gauthier-Villars, Ed. La pollution des eaux continentales. Incidences sur les biocénoses aquatiques, Paris, Pesson.

Apha. 1985. Standard methods for the examination of water and waste-water. APHA-AWWAWPCF Ed., Pensylvania, Washington DC, 1-1150.

Cairns SD. 2005. Révision des *Stylasteridae* hawaïens (Cnidaria: Hydrozoa: Athecata). Science du Pacifique **59(3),** 439-451.

Capblancq J. 1982. Phytoplancton et production primaire. In : R. Pourriot et Masson, Ed. Ecologie du plancton des eaux continentales, Paris, New-York, Barcelone 1-48.

Dussart BH. 1980. Les crustacés copépodes d'Afrique, catalogue et biogéographique. Hydrobiologia **72,** 165-170.

Eawag News. 2012. Dossier : le biotope aquatique-services rendus et besoins. Le magazine de l'Institut de recherche sur l'eau du domaine des EPF **72,** 1-28.

Kengne Tenkeu J. 2014. Physico-chimie de l'eau, Biodiversité et Structure de la Communauté Zooplanctonique du Lac Municipal de Mfou. Mémoire de Master II, Université de Yaoundé I, Cameroun 1-50.

Koste W, Shiel RJ. 1991. Rotifera from Australian inland waters. VII. Notommatidae (Rotifera: Monogononta). Transactions Royal Society of Australian **115,** 111-159.

Legendre L, Watt WD. 1972. On a rapid technic for plankton enumeration. Annual Institute Oceangraphy XLVIII, 173-177.

Lewis WJ. 1987. Tropical limnology. Annual Review of Ecology and Systematics **18,** 159-185.

Madomguia D, Zébazé Togouet SH, Fomena A. 2016. Macro Invertebrates Functional Feeding Groups, Hilsenhoff Taxa as Major Indices of Biological Assessment in Ephemeral Stream in Sudano-Sahelian Zone (Far-North, Cameroun). International cCurrent Microbiology Applied Sciences **5(10),** 792-806.

Mvogo Y. 2017. Biodiversité et physico chimie des eaux du lac Mopa à Bertoua. Mémoire de Master II, Université de Yaoundé I, Cameroun 1-50.

Nziéleu Tchapgnouo JG. 2006. Etude du déterminisme du polymorphisme des Rotifères Brachionidae dans trois plans d'eau de Yaoundé : Lac Municipal, étang de Mélen et étang d'Efoulan. Mémoire de D.E.A., Université de Yaoundé I, Cameroun 1-62.

Nziéleu Tchapgnouo JG. 2016. Faune zooplanctonique du Complexe lacustre Ossa (Dizangué) : biodiversité et structure des populations de Rotifères, Cladocères et Copépodes. Thèse de Doctorat Ph.D de Biologie Animale, Université de Yaoundé I, Cameroun 1-257.

Pourriot R, Francez AJ. 1986. Rotifères. Introduction pratique à la systématique des organismes des eaux continentales françaises. Bulletin Mensuelle de la Société Linnéenne de Lyon **5,** 1-37.

Qiu Z. 2013. Comparative assessment of stormwater and nonpoint source pollution best management practices in suburban watershed management Water **5,** 280-291.

Schlumberger O, Bouretz N. 2002. Réseaux trophiques et production piscicole en étangs fertilisés (Dordogne, France). Revue des Sciences de l'Eau **15(1),** 177-192.

Shiel RJ. 1995. A guide to identification of rotifers, cladocerans and copepods from Australian Inland water. CRCFE Ident. Guide **3,** 1-144.

Tchegnebe W. 2017. Physicochimie et biodiversité de la communauté zooplanctonique de l'étang Noir de Bertoua. Mémoire de Master II, Université de Yaoundé I, Cameroun 1-50.

Tsalefac M, Ngoufo R, Nkwambi W, Djoumessi Tatsangue E, Lengue Fobissie B. 2003. Fréquences et quantités des précipitations journalières sur le territoire camerounais. Publication de l'Association Internationale de Climatologie **15,** 359-367.

Vannote RL, Minshall GW, Cummins KW, Sedell JR, Cushing CE. 1980. The river continuum concept. Canadian Journal of Fishering and Aquatic Sciences **37,** 130-137.

Vikram Reddy M. 2005. Restoration and management of tropical eutrophic lakes. Sciences publishers Inc., Enfield, Plymouth 1-534.

Zalewski M, Wagner-Łotkowska I, Izydorczyk K. 2004. How to assess phytoplankton biomass? In Integrated Watershed Management. Ecohydrology & Phytotechnology –Manual 106-109.

Zébazé Togouet SH, Njiné T, Kemka N, Foto Menbohan S, Niyitegeka D, Nola M, Bilong Bilong CF, Boutin C. 2007. Spatio-temporal distribution of crustacean zooplankton (Copépoda, Cladocera) in a shallow hypereutrophic lake of tropical Africa. Bulletin de la Societé d'Histoire Naturelle de Toulouse (SHNT) **143,** 49-58.

Zébazé Togouet SH. 2000. Biodiversité et dynamique des populations du zooplancton (Ciliés, Rotifères, Cladocères et Copépodes) au Lac Municipal de Yaoundé (Cameroun). Thèse de Doctorat 3ème cycle, Université de Yaoundé I, Cameroun.

Zébazé Togouet SH. 2008. Structure de la communauté zooplanctonique et eutrophisation du Lac Municipal de Yaoundé. Thèse de Doctorat d'Etat en Biologie Animale, Université de Yaoundé **I,** 1-201.